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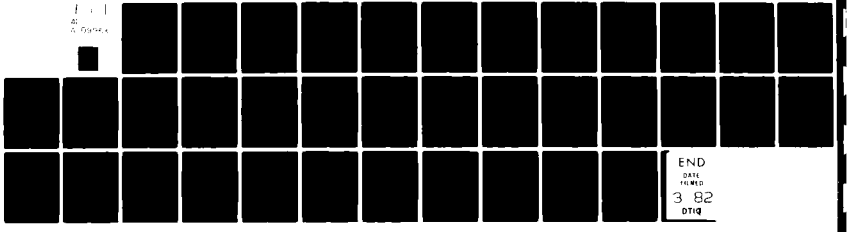

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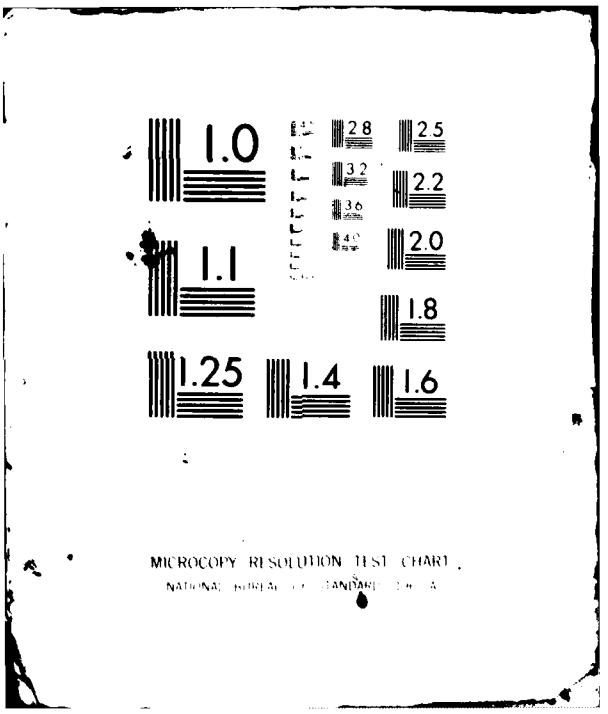
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or, WHY DO RECOVERY MODELS RECOVER SO FAST?

Michael Kennedy and Kevin N. Lewis

June 1981

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by Michael Kennedy and Kevin N. Lewis

The University of Texas, Austin, and The Rand Corporation

Introduction

One of the most important questions defense planners must answer is how much strategic nuclear capability is sufficient to achieve our various deterrence and warfighting objectives. In the case of one planning objective--deterrence by threat of an all-out attack--it is possible to devise simple and intuitive force requirements. Although such impressionistic estimates of the force needs for the so-called countervalue mission may seem unimpeachable, it is necessary nonetheless that we plan forces and employment options on the basis of detailed strategic targeting guidance and appropriate supporting damage models.

Current U.S. targeting guidance specifies that an all-out U.S. strike should ensure that the USSR cannot recover from the effects of nuclear war faster than the United States. So that we should not find ourselves on the wrong side of an economic recovery gap, strategic planners have to assess the recovery potential of the Soviet economy by means of careful inspection of its constituent capabilities. Once this planning task is joined, however, a significant gap divides impression and analysis. While the popular view holds that 100 or 1,000 or 3,000 warheads is enough to finish off the USSR for good, economic analysis frequently suggests that Soviet industrial might can bounce back to prewar levels within a very few years of the most punishing U.S. attacks.

Such findings must be taken very seriously because, to the extent that each side attributes significance to them, they cast doubt on the effectiveness of U.S. retaliatory forces. In turn, requirements for extra forces may be generated and American credibility in the eyes of others (say the Allies) may be undermined. For this reason, review of these models is not simply a question of professional validation and review of theoretical soundness; important policy issues may lie in the balance as well. If, on the other hand, these models do not reflect realistic characteristics of the post-attack environment, then we should not, as a result of our misgivings, risk endorsing the view that the USSR's wartime prospects are better than suspected.

In this paper, we will explain the peculiar result of very rapid recovery that has caused such anxiety in our targeting deliberations. To begin with, we discuss the aims of a U.S. retaliatory blow. Then, we will point out a few of the issues involved in measuring the effects of such strikes. In this context, we will detail, by means of a simple illustrative model, how simple assumptions made in most recovery analyses give rise to apparently speedy Soviet recovery from all-out war. Finally, we shall touch on a few implications of these results for our own nuclear planning.

U.S. Planning for General War Retaliation

The primary mission of U.S. strategic nuclear forces is to deter Soviet aggression against a range of vital American interests. Currently, U.S. war plans are oriented to a variety of contingencies. Two leading themes in all strategic planning are to devise employment options (and thereby to provide a basis for force structure choices)

that seek to gain some kind of military advantage in nuclear fighting, if that is possible, and to govern the escalation of a nuclear war. But because a full nuclear war can do damage that can eclipse the meaning of other war aims, then the issue of stopping a war seems to many people to be our leading strategic objective. In other words, Pyrrhic results can not be the basis for U.S. offensive planning.

Nonetheless, it is conceivable that a nuclear war could escalate to, or even begin at, very intense levels. It is difficult to posit any circumstances that could lead in a credible way to this terrible development. Conceivably the Soviets could impel both sides to this level of conflict. Accident or miscalculation could bring about general war. Or, the United States might deliberately escalate fighting to a major level if it and its allies had been unable to arrest an ongoing war at a lower level of violence on acceptable terms. Even if these scenarios were rejected as implausible, some analysts would say that planning for all-out general war is necessary for the sake of discouraging Soviet challenges at lower levels of violence and in peacetime. Indeed, some writers have even recommended that a nuclear force guaranteeing the destruction of a certain limited number of Soviet cities (that is, a "finite" or "minimum" deterrent force), form the basis of the overall U.S. nuclear posture. Because of its terrible nature, even though it is the least likely contingency, what is generally called "assured destruction" occupies a central place in U.S. strategy.

Like it or not, then, we must plan for the terrifying possibility in which the U.S. is forced to make good on its promise to use strategic

forces against Soviet economic and administrative centers, with the aim of satisfying the national guidance's requirements for all-out war with the USSR. Because this mission may be the cornerstone of deterrence, Soviet economic targets attract many warheads. But despite the large U.S. dedication of forces to this role, disagreement percolates constantly through questions of whether any given level of coverage is satisfactory. More specifically, anxiety exists within the analytic community about U.S. forces programmed for this ultimate retaliatory mission being inadequate to accomplish their retaliatory missions.

To the lay audience, concern with the adequacy of this aspect of the deterrent may seem bizarre, if not downright perverse. Whatever the technical merit of the assertion, the notion that we maintain "nuclear overkill" is deeply entrenched in popular strategic debate. Former President Carter reflected the prevailing view on the subject as he informed the nation that one U.S. missile-launching submarine, "representing less than 2% of U.S. strategic power," could destroy every major city in the USSR.[1] The same "overkill" assumption also can be found in the guise of such supposedly technical statements of retaliatory effectiveness as 400 "Equivalent Megatons" on target, 200 Soviet cities destroyed, 50 or 75 percent of enemy industry wiped out and so and so many pounds of surviving U.S. throwweight delivered. These criteria tend to be associated with calculations which show that these goals can be met using only a small fraction of the nominal aggregate power of U.S. forces.[2]

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[1] President J. Carter, State of the Union Address, January 1979.

[2] For a description of the measures referred to here, see Bruce Bennett, "Methods for Assessing The Strategic Balance," Rand Note N-1441-NA, Santa Monica CA, 1981, forthcoming.

Notwithstanding the raw destructive power of the U.S. arsenal, American war planners must go far beyond such generalized and notional standards of nuclear sufficiency as these for three reasons. First, in preparing large urban/industrial attacks, we still must be mindful of our national military objectives, which should be stated in terms of the means by which the destruction of enemy economic and other targets are expected to translate into outcomes favorable to the United States. Thus, although economic laydowns are usually conceived to be brute force pattern attacks on cities,[3] we actually select aimpoints according to some model of how damage to specific installations would in turn lead to satisfaction of U.S. nuclear wartime targeting policy. "Wipe out 200 cities" is not Executive guidance to the Joint Chiefs of Staff: nuclear employment policy is, to the contrary, framed in precise terms.

Second, a mere "city bashing" attack would not take into account some important features of the enemy's economy. For example, more than 20% of Soviet Manufacturing Value Added lies outside of urban areas. Other nonurban resources including about 38% of the USSR's population, and, of course, key economic sectors including communications, agriculture, energy and mining are widely distributed geographically, so thorough attack planning necessarily becomes selective and articulated.[4]

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[3] See, for examples, A. Katz, "Economic and Social Consequences of Nuclear Attacks on the United States" a Study Prepared for the Joint Committee on Defense Production, U.S. Congress, March 1979; and the Office of Technology Assessment's The Effects of Nuclear War, 1979.

[4] By analogy, in the U.S., 50% of refineries representing 21.5% of capacity are located outside of the largest 71 SMSAs, as are 80% of non-ferrous metallurgical processing; 23% of steel milling; 33% of electronics, etc.

Third, and if for no other reason, we must acknowledge the fact that the USSR might be seriously concerned with relatively narrow and focused criteria for assessing war damage. In this respect, the Soviets might--or so some of their doctrinal statements would lead us to believe--be inclined towards a theory of nuclear war which allowed for some meaning of victory that is not duplicated in prevailing American thought. This definition of victory might, on the one hand, take the form of some general statement of war outcomes, such as the survival of the basic political, military, and internal control elements that ensure the continued integrity of Soviet leadership. Or the USSR could conceivably set some standards which in effect define "tolerable" levels of damage. Even if it was not likely that the USSR would behave in this way, it is prudent to assume that Soviet leadership may either harbor images of nuclear war outcomes unlike those held in the U.S. or might, in a collapsing situation, embrace such views as a "least bad" alternative. That is, and regardless of whether U.S. planners attach military significance to small gradations of damage, we would, under some circumstances, be obliged to express clearly to the Soviets our intention to succeed in spite of any Soviet defensive obstacles or rationalizations.

That being the case, how are the objectives of all-out nuclear strikes set down? The goals of all-out attacks have been known by many titles. In the 1950s, a huge attack on the largest possible inventory of political, economic, and other war supporting targets in or near Soviet urban areas was one component of the military concepts of Massive Retaliation and the Optimum Mix. These doctrines, in turn, gave rise to

plans that were formulated virtually apart from any doctrine or standard of sufficiency for this mission. After 1961, most of those weapons which would be aimed at targets near Soviet population and economic centers were pulled out of the big, single-action military attack of the 1950s, becoming a separate "option" in the new unified U.S. war plan, the "SIOP" (for Single Integrated Operational Plan). Since the early 1960s, two leading frameworks for evaluating its effectiveness in terms of its ultimate retaliatory objectives have been widely discussed in the public press.

First, through the early 1970s, according to successive Defense Reports and other official statements, the U.S. aim in a full nuclear attack on the USSR would have been the execution of an "assured destruction" attack with the goal of destroying the "viability" of the Soviet economy. The objective of destroying viability, in theory, requires that the USSR be rendered incapable of satisfying, out of residual production, demands arising from surviving population and enterprises, and that stocks that do survive are insufficient to sustain the economy during its attempt to restore adequate output. In operational terms, as Secretary McNamara said, the U.S. needed to pose the constant threat to "destroy the attacker as a viable 20th century nation."[5]

Second, beginning in 1973-74, the task of destroying viability gave way to that of retarding the recovery of the USSR after nuclear war. The planning guidance was changed, noted General Jasper Welch in 1979, because there was anxiety that the U.S. targeting process, as pursued in

[5] Robert McNamara, Department of Defense Annual Report for FY68.

the 1960s, somehow was "not appropriate." Welch said SIOP preparation

> "proceeded year-after-year from 1960 and it was not until the early 1970s that a significant concern about how that was being done arose. This concern led to a study, the NSSM-169, for re-evaluation of how the strategic employment policy would be conducted....
>
> This study...led one year later to the NSDM-242 which was the Presidential statement of nuclear employment policy which is still valid today."[6]

Among other things, the new aims for war planning set forth in this strategy owed their creation to the shift in the strategic balance; to a desire by President Nixon to depart (at least in appearance) from the declared nuclear strategy of Presidents Kennedy and Johnson; and to U.S. concern with increased Soviet efforts in the fields of civil and active aerodynamic and ballistic strategic fefenses. According to one study of targeting literature,[7] the new strategy was also adopted because none of the then available technical evidence strongly supported the proposition that either the U.S. or Soviet Union would be able to destroy the other's viability. Be that as it may, the aim of the new U.S. doctrine, according to Donald Rumsfeld, was as follows. "If the Soviet Union could emerge from (a strategic nulcear exchange) with superior military power, and could recuperate from the effects more rapidly than the United States, the U.S. capability for assured retaliation would be considered inadequate."[8]

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[6] Hearings on Military Posture, DoD Authorizations for Appropriations for FY80, Part 3, Book 1, p.17.

[7] H. Berger, "A Critical Review of Studies of Survival and Recovery after a Large-Scale Nuclear Attack," R&D Associates, RDA-TR-107006-009, Marina Del Rey, CA, December 1978.

[8] Donald Rumsfeld, Annual Defense Report for FY78.

How is Retaliatory Effectiveness to be Measured?

Whether or not the post-attack viability of the Soviet Union is assured, the attack assessment modelling problem basically is a matter of predicting and characterizing the significance of different sets of aimpoints for Soviet recovery prospects. If we are trying to destroy Soviet viability, we are in practice trying make sure that the USSR cannot reorganize with sufficient speed to commence the arduous trek along the recovery path in the first place. Under the newer doctrine, we are trying to delay Soviet progress. For this reason, we primarily are looking, with the anti-recovery scheme, at the same economic targets as before (though we may place different emphases on particular Soviet resources.) Though the targeting problem has not changed dramatically for two decades, nominal shifts in U.S. aims and other developments related to declaratory U.S. policy and to limited nuclear war strategies have precipitated an acrimonious debate. It continues to this day and tends to concentrate on some of the abstract ramifications of alternative all-out war strategies.

While these gyrations proceed, we are still charged to overcome theoretical obstacles, at least to the point where we can apply our economic targeting doctrine to the job of translating war aims into that fatal list of aimpoints to be destroyed in the event of general war. Moroever, in placing a candidate plan before the President and the Joint Chiefs of Staff for review and approval, we must be prepared to justify explicitly the tactical principles underlying our choice of targets. Returning to the matter of national targeting guidance, it is certainly disagreeable that no matter how simple and reasonable our retaliatory

aims look on paper, it is hard to generate a targeting theory in which we can have high confidence. Note that this is not a problem necessarily prevailing throughout targeting. In other cases, say with Soviet silos, we can pick a desired level of damage and commit weapons in a straightforward manner so as to attain that level of destruction for all of the targets concerned. But for economic attacks, appropriate figures of offensive merit are not so obvious.

Targeteers therefore face a difficult task. They must reconcile the practical business of war planning with the theoretical principles expressed in the national guidance which undertake to address the relevance of all Soviet economic capabilities to more generalized statements of enemy potential (such as the "military power of the Soviet state") that we might consider important objectives. On the basis of targeting analyses, we can review the issues that characterize the sufficiency of the forces we program for these missions. But uncertainties inherent in the mathematical expressions of the various economic retaliation philosophies can be upset by apparent shifts, in the operational context, which in turn drive U.S. offensive force requirements. For this reason, our major economic attack options may appear inadequate if one of two things happens.

First, the enemy might manage to outstrip our offensive potential by deploying so many (or sufficiently hard) targets that we cannot cover them all. All available evidence suggests, however, that the Soviet economic target system has not changed over the past two decades in such a way as to severely jeopardize the U.S. ability to generate the

damage levels on key targets that may have been listed in Presidential guidance for the employment of nuclear weapons.[9]

The second source of uncertainty in U.S. potential, and (indirectly) the seeming explanation for some of the technical concern with the U.S. ability to destroy the Soviet economy, lies with the models used to assess the consequences of an American strike on the USSR. The theoretical principles used to weigh the sufficiency of American attacks, and not shifts in targets, may in fact be the chief determinant of the concern expressed by some with the current capabilities of U.S. nuclear forces. Requirements for forces have in this way been subject to upward pressures for reasons not relating simply to shifts in the target base.

To assess the consequences of shifts either in the target base or in damage methodologies, we must refer in turn to the specific criteria used to estimate the outcomes of urban/industrial attacks. In other words, how, specifically, are the requirements for assured retaliation or assured destruction (or any other objective) stated? Not surprisingly, no formulation put forward yet has satisfied all observers.

Secretary McNamara contended publicly that 400 Equivalent Megatons on Soviet cities was sufficient to destroy their viability. However, McNamara's intention was not to specify the size of the force "required" for assured destruction of the USSR as a viable nation: rather, this statement of forces was intended to suppress what seemed to McNamara at the time to be inappropriate and excessive service requests

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[9] Director of Central Intelligence, Soviet Civil Defense, NI78-10003, July 1978.

by some for new strategic nuclear delivery systems. The 400 EMT figure subsequently has been diluted, since it has proven possible, by adjusting various weapon and targeting parameters, to prove that the force is "incapable" of executing an all-out blow defined in this way.

Because highly specific public statements of urban/industrial attack sufficiency have invited requests for extra forces, subsequent authoritative statements have tended not to be explicit in how much was enough for this mission. For example, Clark Clifford said that the effectiveness of the strategic forces was gauged by "their ability, even after absorbing a well-coordinated surprise strike, to inflict unacceptable damage on the attacker;"[10] Melvin Laird suggested that U.S. forces were adequate if they threatened potential aggressors with "unacceptable risks."[11] And James Schlesinger said that deterrence was based on "assured retaliation" which demanded the ability to inflict "irreparable damage" on the USSR.[12]

Only recently, in fact, has the problem been posed in relatively more specific terms. The set of component targets in the economic base has been increased, and commentators also speak in terms of such combat objectives as enemy leadership potential, ethnic fracture points, and energy production. To implement the more detailed attack plans implied by the NSDM-242 anti-recovery targeting guidance mentioned above, Secretary Rumsfeld estimated in his FY78 Annual Report that 8500 weapons were required to implement the new guidance, i.e. "retard significantly the ability of the USSR to recover from a nuclear exchange and regain the

[10] Clark Clifford, Annual Defense Report for FY1969.
[11] Melvin Laird, Annual Defense Report for FY1971.
[12] James Schlesinger, Annual Defense Report for FY1975.

status of a 20th century military and industrial power more rapidly than the U.S."[13] Secretary Brown one year later expressed the more restrained view that the destruction of 200 cities at a minimum would do the same job. Even that announcement may have been too much of a temptation to those who would use that statement to support extra force requests, however. Since his FY79 Report, Brown has made no such specific statement on U.S. retaliatory requirements.[14] As reticent as Brown may have been subsequently, however, it is known that U.S. targeting still is undertaken roughly on the same pattern as the plans developed in the early 1970s.

Since about 1977, the strategic debate has seen a rise in concern with the sufficiency of U.S. retaliatory forces. This debate has been connected with SALT II's meanderings, with the need to decide on the shape of the U.S. strategic program for the 1980s with rediscovery of expanded Soviet civil and active defense efforts, and with certain adverse trends in the strategic balance. In connection especially with worries about Soviet civil defense, many technical reports have appeared which contend that the U.S. cannot satisfy the "assured retaliation" doctrine's requirement that the USSR not recover more quickly than the United States in the aftermath of general war.

Much of this debate has been conducted only on an official or classified level, but some prominent assessments in the open literature have alleged that the USSR can recover from even an all-out U.S. strike in the short interval of four at the least, and on up to fifteen years

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[13] Donald Rumsfeld, op. cit.

[14] See Harold Brown, Annual Defense Reports for FY1979, FY1980, FY1981.

at the outside, depending on the severity of the U.S. attack and the performance of Soviet civil defense. Typical results suggest full recovery to prewar GNP within about five years if a U.S. attack destroys, say, less than half of Soviet capital and relatively little labor; seven to ten years with population only civil defense; and, perhaps, fifteen years in any event. The U.S. force committed to the attack in such models often runs to several thousand warheads.[15]

Explaining Very Rapid Economic Recovery from Nuclear Attack

In short, the conclusion of many analyses is that, even in the face of full SIOP-level urban industrial attacks, the attacked economy can quickly regenerate economic output, measured specifically in terms of arms stocks, industrial output, etc. This result seems excessively optimistic: with more than, say, half the pre-attack capital stock, arms inventories, and labor force destroyed, how can an economy rebuild these capabilities to pre-attack levels in only a few years? The next few pages explain this fundamental and pervasive characteristic of economic recovery modeling.

We will do so by presenting a simple example of this type of model, and analyzing its behavior. The example we present is kept simple so that both the basic economic relations in it and the way that these relations lead to the kinds of results described above will be transparent. This simple model will illustrate the internal workings of

[15] For some leading unclassified examples, see: T.K. Jones, "The U.S.-Soviet Strategic Balance: Options and Non-Options," Journal of International Relations, Fall 1977; Jones and W. Scott Thompson, "Central War and Civil Defense," Orbis, Fall 1978; and J. Pettee et al., "PONAST II Vugraphs," Office of Civil Preparedness, 1971.

the more complex models actually used in recovery analysis, and show the reasons why these models get the results they do.

A danger of using a simple model, of course, is that the additional detail of the larger models may add basic new content to the analysis, to the extent that our smaller model is not an accurate analogue. We feel this caveat does not apply to the class of models used in recovery analysis, and that the simple model we have chosen reflects faithfully those basic economic relations that drive the larger models. Thus, we maintain that our conclusions about why recovery models recover so fast can be applied intact to the larger models. After a presentation of our simple model, we will discuss the kinds of additional structure that more complex models have, and the *effect* the additional structure would have on analytic results.

We now proceed to a description of our model. The economy we are considering produces three kinds of output: consumer goods, investment goods, and military output. This output is produced by two factors of production: labor and capital. Capital is simply the stock of physical assets that are used to produce output: factories, machinery, office buildings, warehouses, commercial vehicles, etc. It is, of course, exactly these physical assets, located in a finite number of installations, that are targeted in an economic attack.

Military output, for example, consists of production of weapons and the maintenance of military strength. Weapons are produced by capital (weapons factories) and labor (workers in those factories). Military strength is likewise produced by capital (bases, airfields, depots, command and communication facilities, etc.) and labor (military

personnel). Both of these kinds of military capital are prime target candidates; the goal of their destruction is the reduction of the amount of military output that can be produced after an attack.

Before we continue, a special word about investment goods output is in order, because it plays a large role in analysis of the recovery process. Investment goods output is simply the production of new capital goods--that is, the production of new factories, warehouses, military bases (an output of the construction industry), and the production of new machinery and equipment that is in turn used to produce other goods (the output of the machinery sector). New output is used to augment the productive capacity of the economy by adding to the capital stock; that is, by increasing the number of factories (and the equipment inside them) so that more of all kinds of goods can be produced. The output of this sector is vital in rebuilding and recovering after a counter-economic attack, for the goods produced by this sector are used to replace destroyed structures and machinery. These investment goods are themselves produced by capital and labor, of course, by factories that make machinery and building materials (capital) and by machinists and construction workers (labor).

Our model is summarized in Figure 1. The boxes in the first row represent the capital stock of the economy. There is a separate box for the capital used in producing each kind of output; this represents our assumption that capital goods, once built, can produce only the kind of output they were designed for. This assumption is called <u>non-shiftability</u> of capital in technical terms, and means, for example, that factories built to produce consumer goods <u>cannot</u> be used to produce

military goods. (The implications of relaxing this assumption will be discussed below.) Thus, our model will not recover quickly because we are allowing surviving physical productive assets to be modified to produce exactly the goods that are needed for recovery.

The next row of Figure 1 shows a single box for labor, and the arrows indicate that it can be allocated to produce any of the three kinds of output. This shiftability assumption is the opposite of our capital assumption, and implies that workers originally employed in consumer goods plants can be reassigned to (say) military equipment plants (provided they exist) and produce military goods in them. Again, we will discuss the consequences of modifying this assumption below.

Finally, Figure 1 indicates that labor is used with the three specific types of capital stock to produce the three kinds of output. The dashed arrow shows that the investment goods output is used to add to the capital stock so that production of the three kinds of output can be increased in the future. The sum of consumer goods, investment goods, and military output is the gross national product (GNP) of the economy.

We will use this simple economic structure to illustrate the effects of an attack on the economy. It is convenient to begin the analysis with a picture of the base, or pre-attack, economic situation. This is given in Table 1. It shows the level of the capital stock, labor force, and production of each of the three kinds of output. We note a few aspects of this economy. Investment goods constitute 20 percent of GNP; the capital output ratio is 2.5; and military output is 10 percent. These numbers are characteristic of those national

DIAGRAM OF RECOVERY MODEL

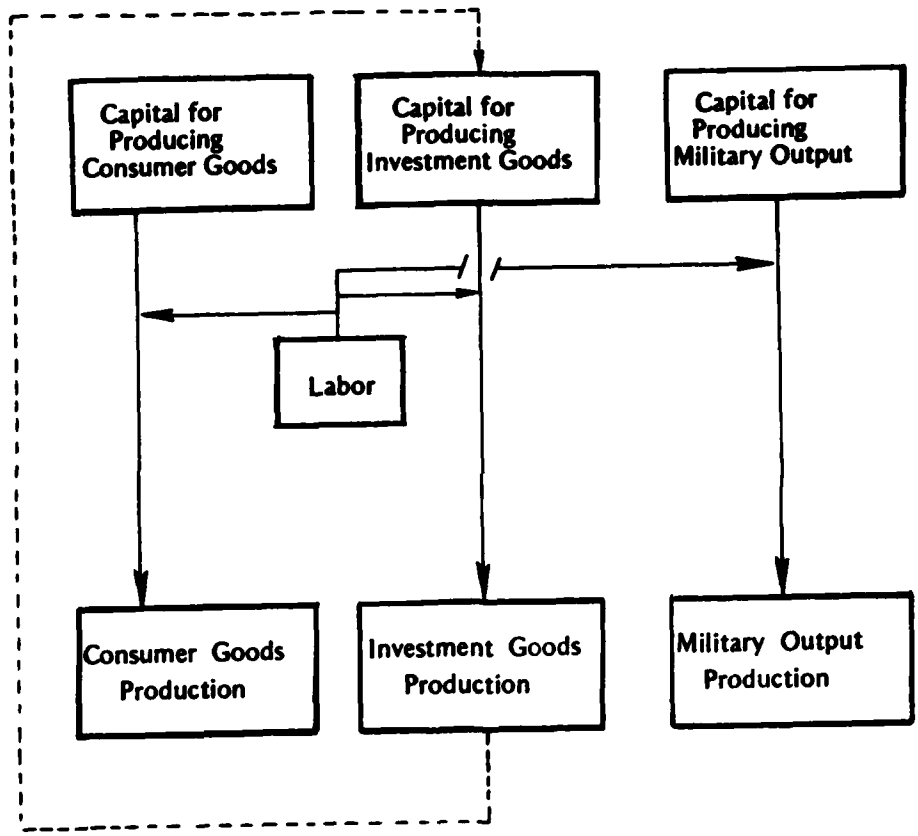

Fig. 1

economies in which recovery modellers are generally interested. The "per capita consumption index" is simply an index of the ratio of consumer goods output to the labor force.

Table 1

PRE-ATTACK ECONOMY

ECONOMIC SECTOR	CAPITAL STOCK	LABOR FORCE	OUTPUT
Consumer Goods	175	70	70
New Capital Goods (Investment Goods)	50	20	20
Military Output	25	10	10
	250	100	100
	(Total Capital Stock)	(Labor Force)	(GNP)

[Per capita consumption index = 1.00.]

We now impose a fairly severe attack on the economy that destroys half the capital stock in each sector and half the labor force. (This again is roughly characteristic of the kinds of numbers used in recovery analyses.) What effect does this have on the economy? Our model provides the desired results if we make two assumptions:

A.1 The "survival" or "reorganization" phases of the post attack period are assumed to have passed. Post-nuclear attack analysis traditionally has divided the aftermath of an attack into two phases: During the first (which itself has been characterized as, or subdivided into, the "survival" or "reorganization" phases), the surviving political leadership of the attacked nation regains effective police control, provides and distributes sufficient food and medical supplies to stabilize the size and composition of the population, and achieves sufficient control

over available economic administrative mechanisms so that its allocation and production orders are carried out. In addition, it is assumed that communication and transportation networks are restored to the point where national production can be effectively coordinated. This phase is considered to be over when the pre-attack technical laws of the economy again hold. This means that a given amount of labor in a given capital facility (i.e., plant with its equipment) will produce the same amount of output as it did before the attack.

Economic recovery models are generally silent on the issue of the length of this initial post attack phase. Once it has been completed, the "recovery" phase begins, and economic models predict the course of the economy from that point.

A.2 Our second assumption is that of constant returns to scale (CRS). All economic recovery models embody at least a close approximation to this assumption. The assumption says that if the capital and labor used for producing a certain kind of output are reduced by a given, equal percentage, the amount of output of that kind actually produced will fall by the same amount. It has intuitive appeal if one thinks in terms of a certain percent of the facilities being completely lost, along with their workers. The surviving factories could produce exactly what they had produced before, and the proportionate reduction in total output would be simply the proportion of factories lost.

The combination of these two assumptions enables prediction of a post attack economy, beginning just at the moment the recovery process is about to commence, as shown in Table 2.

The first two columns show our assumptions about the results of the attack; the capital stock available for producing each kind of output has been reduced by half, and the total labor force has also been halved. Assuming that workers are allocated to capital facilities in the same proportions as before the attack (an assumption that will be explained below), the resulting output will be as shown in the last column. Not surprisingly, due to A.2, this output is exactly half that which was produced before the attack. Thus, GNP is 50, half the pre-attack GNP, and the per capita consumption index is the same as before the attack, since the labor force has fallen the same amount as consumption goods output. Our simple model (and all more complex models) thus predicts that once the economy has been reorganized so that surviving assets are employed with the same effectiveness as they were before the attack, an attack that destroys one half the assets will result in an economy that produces at one half the pre-attack level, and at the same per capita level.

Table 2

POST-ATTACK ECONOMY: ECONOMIC ACTIVITY WHEN RECOVERY BEGINS

ECONOMIC SECTOR	CAPITAL STOCK	LABOR FORCE	OUTPUT
Consumer Goods	87.5	35	35
Investment Goods	25	10	10
Military Output	12.5	5	5
	125	50	50

[Per capita consumption index = 1.00.]

The result is not, of course, the surprising "rapid" recovery that most models show. This simply gives us a starting point for recovery analysis. Indeed, it is a starting point with output at one half the pre-war level, a considerable drop in historic terms. The interesting question then is how quickly these output levels can be restored to pre-attack levels or beyond, and how this restoration is possible. To analyze this question, we now consider the progress of the economy, from the starting point shown in Table 2, through time. In performing this analysis, we make three additional assumptions:

A.3 We assume a condition of shiftability of investment. This crucial assumption says that investment goods output can be used to rebuild any kind of capital. A certain amount of new capital goods will be produced each year by the the investment goods sector (for example, 10 units in Table 2), and we assume that these new capital facilities can be built so as to produce any kind of output. Put another way, the structures and machinery newly produced by the investment goods sector in any year can be used to add to (or rebuild) any of the three kinds of capital stock. For example, the surviving military capital stock in Table 2 is 12.5 units; assumption A.3 says that if all new investment goods (10 units) were used to rebuild military capacity, this capital stock could be increased 80% the first year.

A.4 Our second new assumption is that of prioritization. That is, the leadership of the post-attack economy can designate some sectors as priority ones, and rebuild their capacity first while letting the output of other sectors stagnate.

A.5 We temporarily introduce a last assumption of no capital-labor substitution. This says that in order to produce output, labor and capital must be used in exactly the pre-attack proportions. In other words, it says that a given capital facility, such as a factory, can produce only as much output as it did before the attack, no matter how much additional labor is employed in it. Equivalently, it says that any reduction in labor used in the factory will cause a proportionate reduction in output. (This assumption justifies our allocation of labor across sectors in Table 2, since any other allocation would have reduced output in one sector without increasing it in others.) This assumption will be relaxed later in the paper, and the alternate assumption that output from a plant can be increased by using labor in excess of pre-attack amounts will be substituted.

Given these assumptions, let us examine the path of the economy through time. We will assume in this example that the priorities of the economic leadership in the recovery period are such that they only rebuild the investment goods and military output sectors--i.e., that all new capital is used to rebuild the facilities that produce these kinds of goods. We assume that they rebuild these two capital stocks in the pre-war proportions of two units of capital for producing capital goods to one unit for producing military goods.

Table 3 traces the economic path of this economy through a few years. The first two columns show the level of capital (and thus of output) in the military and investment sectors. These levels (and, in

parentheses, the per year increments to them due to production and installation of new capital goods) are traced through time down the columns. Thus, we see in period 1 the following surviving capital stock in each of the sectors: 25 in investment and 12.5 in military, as in Table 2. The last column shows GNP (or the output of each of three kinds of goods) in each period. Output of I and M goods are simply proportional to the amount of capital stock available for producing them. (How output of C, of consumption goods, is determined will be explained momentarily.) Therefore, the last column shows output of 10 in the I sector and 5 in M, again corresponding to the figures in Table 2.

We will now inspect the continued evolution of the system through time. The first period output of new capital goods, 10, is available to be added to existing capital stocks, i.e., available to rebuild part of the attacked economy. Using the allocation (or prioritization) assumptions made above, we use none of this to rebuild capacity for producing consumer goods, and divide the total between investment and military sectors in the proportion 2:1. This means that 6.7 is added to the capital stock used for producing I goods, boosting the level of that stock to 31.7, and 3.3 is available for rebuilding the capacity of the M sector, increasing that capital stock to 15.8. These new investment activities are shown in the second row, and the resulting capital stocks available for year 2 in the next row. Then, using our no capital-labor substitution assumption, we can derive that output of I goods will be (31.7/2.5), or 12.7, in the second year, and output of M goods will be 6.3. Then again, this investment good output, or new production of plants and machinery, is used to further augment production capacity in

Table 3

POST-ATTACK ECONOMIC EVOLUTION
(Assumption: All New Capital Goods Divided According to Ratio 2:1 Between Rebuilding I-Sector and M-Sector)

	Capital Stock in I-Producing Sector	Capital Stock in M-Producing Sector	GNP	
			35.0	C
Year 1	25.0	12.5	10.0	I
			5.0	M
New Investment After Year 1	(6.7)	(3.3)		
			31.0	C
Year 2	31.7	15.8	12.7	I
			6.3	M
New Investment After Year 2	(8.5)	(4.2)		
			25.9	C
Year 3	40.2	20.0	16.1	I
			8.0	M
New Investment After Year 3	(10.7)	(5.4)		
			19.5	C
Year 4	50.9	25.4	20.4	I
			10.1	M

the economy, and so on. The bottom line is perhaps the most startling: in the 4th period, output of the M and I sectors is restored to the pre-attack level. This example illustrates the essential results from the actions of the two mechanisms, shiftability of investment and prioritization, that lead to rapid recovery of key economic capabilities in post-attack models. The reader may want to work out the alternate

case in which investment is split in exactly the pre-attack proportions (7:2:1) among all three capital stocks.

We have one loose end to tie up here: what happened to labor? According to our strict "no substitution" assumption, when the plant, or capital stock, of a sector is increased, workers there must be proportionately increased also. This means that of the surviving labor force of 50, 30.5 must be engaged in production of new investment goods or military output by the fourth period. This leaves only 19.5 in the consumption goods production sector, and <u>again</u> by our strict no substitution assumption, output of consumption goods must then fall to 19.5. However, across the entire four-year horizon, <u>per capita</u> production of consumer goods is 80 percent of the pre-attack level. In terms of prioritization, we generally assume the population will be made to do with less after an attack, and this allotment of goods for consumption seems generous.

We now consider a second example of a post attack economic evolution, to illustrate the sensitivity of these kinds of results to changes in assumptions. Here, we replace assumption A.5 by assuming instead the possibility of capital-labor substitution, that is, that a given plant can increase its level of output if additional labor is used in it. In particular, we will assume that if the number of workers is doubled, output can be increased by one-half. (This is approximately the degree of substitutability implied by a Cobb-Douglas production function with a labor coefficient of 0.6.) Finally, we will assume that <u>only</u> the investment goods sector is rebuilt, and that the level of military output is allowed to remain at one-half the pre-war level.

The combination of these two assumptions, of course, will greatly increase the ability of the post-attack economy to increase its output of new capital goods, and thus to rebuild its civilian capital stock. This capital stock will have a different composition than the pre-war stock, though; it will be heavily weighted toward industrial production and away from consumer good production. This overall situation is roughly analogous to the heavy Soviet industrialization drive of the 1930s.

In a more complex example allowing capital-labor substitution, one must decide how much labor is allocated to each sector. For simplicity, we'll assume that exactly enough workers are assigned to plants in the investment goods producing sector so that the output-capital ratio is increased to .6 (i.e., the capital output ratio falls to 1.67), or that a given investment goods plant does, in fact, increase its output to one and a half times the pre-attack level.

Table 4 traces the path of such an economy over time. It is exactly analogous to Table 3, except that the military capital stock column is omitted. Here, the first period capital stock available for production of investment goods is 25 as it was in Table 3 (this 25 is just the amount surviving the attack). However, in this example, by assumption, output of new capital goods, or new plant, can be increased from 10 (the one-year level in Table 3) to 15 by reassigning workers in other sectors of the economy to work more intensively surviving plant. This first period output of new capital goods is used solely to rebuild the capital good producing, or investment, sector, again by assumption. Thus, we add the 15 units of new plant to the 25 surviving the attack

and get 40 units of plant and equipment available for producing new capital goods in the second period. Again, by adding more workers, we can operate at an output:capital ratio of .6, and thus produce 24 units of investment goods in the second period. And so on.

The end of this process after only four years is startling indeed: output of capital goods is three times the pre-attack level! In addition, if the surviving capital in the M and C sectors (12.5 and 87.5, respectively) is added to fourth period capital in the I sector (102.4), we get an economy-wide capital stock of 202.4, over 80 percent of the pre-attack level. Thus, if we make these substitution and

Table 4

POST-ATTACK ECONOMIC EVOLUTION
(Assumptions: Capital-Labor Substitutability. All New Capital Goods Used to Rebuild I-Sector)

	Capital Stock in I-Producing Sector	GNP
Year 1	25.0	15.0 I 5.0 M
New Investment After Year 1	(15.0)	
Year 2	40.0	24.0 I 5.0 M
New Investment After Year 2	(24.0)	
Year 3	64.0	38.4 I 5.0 M
New Investment After Year 3	(38.4)	
Year 4	102.4	61.4 I 5.0 M

prioritization assumptions, we see how surviving productive capacity as a share of the entire economy comes close to that of the pre-war situation. (Recall the different structure of the economy.) This reflects the inexorable logic of geometric compounding, a fundamental aspect of all economic growth models.

We will now discuss the aspects of the more complex models actually used in recovery analysis that may cause them to give different sorts of results from the ones presented here. First we will discuss those assumptions that may lead to slower recovery paths than the ones predicted by our simple model.

1) Non-shiftability of investment. A crucial assumption of this analysis was that new investment goods could be used to rebuild any sector, thus enabling the rapid recovery of military and/or industrial output at the expense of consumer goods. One might want to modify this assumption so that not all new capital could be used to rebuild priority sectors. The obvious way to implement this would be to disaggregate the investment goods sector into three: one that produces capital goods used for consumer goods production, one that produces capital goods for investment goods production, and one that produces capital goods for military output production. To our knowledge, however, no recovery model incorporates this disaggregation: all models contain homogeneous "machinery" and "construction" sectors. To slow down predicted recovery rates, some models may put constraints on the rate at which military or industrial capital stocks can be rebuilt, but these constraints reflect the judgement of the analysts and not the structure of the models.

2) Input output and intermediate goods. Most recovery models have a considerably more complex economic structure than the one presented here, and include basic industries (such as metallurgy), resource industries (such as agriculture), and intermediate processing industries (such as oil refining), all of whose outputs are intermediate goods eventually being transformed into final consumer, investment, and military products. However, this does not change our results since the use of the outputs of these intermediate industries can be prioritized as easily as investment can, and they can simply be routed to the appropriate final processing plant. The fact that more transportation and communication links are needed in a more complex economy may prolong the "reorganization" period, of course, and will make appropriate economic coordination more difficult during the recovery phase. However, no formal recovery model incorporates the coordination function, and all models instead simply assume it can be accomplished. The existence of intermediate industries in fact may make recovery easier, since it makes capital shiftable in the sense that a plant that had made steel that eventually wound up in consumer goods before the attack could make steel that goes to military production afterward.

3) However, the existence of intermediate industries does lead to the possibility of bottleneck targeting. If a crucial link in the economy (such as oil refining) could be completely destroyed, recovery might be very difficult. However, the possibility of prioritization of output counteracts the bottleneck threat; if only a small amount of a key sector's capacity survives, it can be used in crucial production areas, and in particular, in producing goods needed to rebuild that capacity!

4) Furthermore, labor may not be freely shiftable across sectors. However, this could be offset by the possibility that some kind of capital may be shiftable. (For example, civilian auto and truck plants may be adaptable to military vehicle production.)

Finally, certain complexities incorporated in larger models will in fact make recovery faster than indicated by our simple model. These include recruitment of more persons into the labor force, double shifting, and optimal allocation of labor and investment resources rather than the rule of thumb allocations used in this paper.

Conclusions

In the previous few pages, we have documented the general effect of the three recovery model phenomena of:

1. shiftability of investment--basically a technological issue;
2. prioritization--a political, or more specifically, a leadership issue; and,
3. capital labor substitutability, another technological question. The post-attack society, even after a severe SIOP-level attack, is shown to rapidly restore levels of output in key economic areas, such as military force and industrial output. This is done by consciously directing resources (labor and new investment goods) into rebuilding specifically those sectors.

What do these results, which reflect certain general properties of, albeit, more complex and bulky models imply about targeting? A few points come to mind.

Perhaps an effort should be made to attack those plants that produce capital goods which are specific to rebuilding the sectors we are concerned about. That is, if we can find areas where the

"shiftability of investment" assumption is patently contradicted, we can exploit this vulnerability by targeting heavily those plants that produce machines used to produce goods whose output we are interested in seeing suppressed. (For example, if a certain kind of electronic equipment is needed to produce missile guidance systems, and if only a few plants can produce this equipment,[16] then if those plants are knocked out, it will be impossible to restore missile production until both the missile plants themselves and the specific equipment plants are rebuilt.[17]

This notion endorses the generic targeting theory of "bottlenecking" which has been at the heart of U.S. air war planning since the 1930s. This assumption forms the core of a useful strategy because it assists in force sizing and makes possible more confident estimation of the consequences of attack. Moreover, it allows us to selectively expand the data bases we use in recovery analysis, thereby avoiding a pitfall of standard Input/Output modelling, namely, an unregulated increase in the number of sectors in an economy with a concomitant dramatic growth in the complexity of the problem.

Three difficulties arise with this strategy, however. First, identification of such plants may be very difficult and uncertain at best. In the broadest sense, we have not identified all industrial value and complete and precise economic intelligence is difficult to accumulate. A second issue, one of prudent efficiency (or risk

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[16] Note the importance here of "can" as opposed to "do."

[17] See J. Leavitt, "Analysis and Identification of Nationally Essential Industries, Volume I," Institute for Defense Analysis P-972, March 1974, on the question of locating such bottlenecks.

aversion) in targeting arises here: do we want to expend a large number of weapons on a few plants (at the cost of other targets that we could not then bring under attack) that we think may be crucial for rebuilding key sectors? A collateral problem is that the adversary can probably identify such crucial capital goods producing sectors as well, and may take steps to harden and/or disperse the plants. Finally, we may not have a suitable appreciation for the ability of the other side to "jury rig," substitute, draw from stocks and inventories, or obtain (by capture) resources from nations it can subjugate in the course of fighting. To devise an effective bottleneck strategy therefore requires resolution or compensation for these possibilities.

A related strategy would be to concentrate targeting on the capital goods producing industry itself, i.e., to try to draw down the capacity of the industry that itself produces the goods necessary for rebuilding any sector. The problem with this strategy is that machine building and construction are typically greatly dispersed in a modern economy, and targeting a high percentage of their capacity with confidence is very difficult (and can be made much more so by countermeasures such as stockpiling, camouflage, dispersal, and hardening).

In this context, "survival" and "reorganization" become relatively more important subperiods of the canonical post-attack pathway, because they intervene between the attack and the beginning of recovery. Of course, it is not understood at all how to translate the relative objectives of massive attacks into the length or difficulty of each period, let alone to define them in terms of observable phenomena. Note that this particular question lies at the roots of the theoretical

differences encountered in comparisons of "assured retaliation" with "assured destruction."

Reconnaissance, retargeting, and continuing attack become very attractive options for "keeping them down." The survivors can concentrate their resources on rebuilding plants that produce outputs of special importance to them (and which may pose a special threat to us). By the same token, we can attempt to frustrate these efforts by identifying and attacking the rebuilding and rebuilt assets. This factor definitely has implications for the missions and roles of the strategic reserve forces in the case of economic targeting.

Although it is only implicit in the preceding examples, the importance of labor survival for economic progress after an attack is a function of the degree of capital labor substitutability. A related factor of unpredictable significance is the state's ability to organize surviving labor into a coordinated productive effort and to maintain confidence in the rebuilding effort, thereby ensuring momentum in recovery. When contemplating force allocations in SIOP planning, it is also essential to keep in mind those management, geographic, demographic, transportation, and regional issues which will influence all elements of the recovery economy. There will be questions that cannot be answered with quantitative finality which ultimately would determine the effectiveness of labor reorganization. These issues include currency reform, devotion of resources to internal security pursuits, etc. But in both theory and in previous experience it has seemed as though surviving (especially skilled) population has been the lynch-pin of recovery. Therefore the demographic issue is critical.

So, too, with management, transportation, and other infrastructural features of the problem.

Finally, as one economist studying this problem has noted, the importance of economic models in analyzing the post-attack world is that they incorporate the fact that military output is embedded in a larger economy, and can, therefore, deal with the economy-wide resource constraints that limit possibilities for military reconstitution. The sentence is true, but its emphasis seems wrong. Economic models basically allege that since resources (new capital and labor) are flexible and can be directed to many uses, by letting low priority economic activities (such as non-subsistence consumption) stagnate, the post-attack society can rebuild important economic capabilities relatively quickly.


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